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Efeitos biomecânicos de diferentes materiais e espessuras de placa estabilizadora oclusal sobre próteses unitárias implanto-suportadas em simulação de sobrecarga: análise por elementos finitos 3D

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Orientador: Prof. Dr. Victor Eduardo de Souza Batista
Coorientadora: Profa. Dra. Roberta Okamoto
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*‘‘Permanece o perfume das flores
nas mãos que ofertam rosas’’.*

Waldecir José Sabioni

RESUMO

COSTA, L. A. **Efeitos biomecânicos de diferentes materiais e espessuras de placa estabilizadora oclusal sobre próteses unitárias implanto-suportadas em simulação de sobrecarga**: análise por elementos finitos 3D. 2025. Tese (Doutorado) – Faculdade de Odontologia, Universidade Estadual Paulista (UNESP), Araçatuba, 2025.

O objetivo deste estudo foi avaliar o efeito de diferentes materiais utilizados para a fabricação da placa estabilizadora oclusal (PEO) e as diferentes espessuras desses materiais na distribuição de tensões sobre próteses unitárias implanto-suportadas parafusadas. Para isso, foi utilizada a análise de elementos finitos 3D para a simulação de sobrecargas oclusais sobre o parafuso de fixação da coroa protética ao implante, implante dentário e tecido ósseo cortical ao redor dos implantes correspondentes à porção posterior da maxila direita, na região do primeiro premolar, segundo premolar e primeiro molar. Dez modelos foram simulados em programas específicos de desenhos 3D para representar três implantes unitários de hexágono externo (HE) (Ø 4,0 x 7,0 mm), cada qual com uma prótese metalocerâmica unitária parafusada. A PEO foi simulada com 3 materiais diferentes, sendo polimetilmetacrilato (PMMA), etileno-acetato de vinila (EVA) e poliéter-éter-cetona (PEEK) nas espessuras de 1 mm, 2 mm e 3 mm. Além disso, a um modelo foi aplicada sobrecarga sem a utilização da PEO. Por fim, todas as geometrias foram exportadas para discretização no software específico para elementos finitos. Neste mesmo software, foi simulada carga estática parafuncional de 800 N nos dez modelos, em direção axial, em 11 pontos na superfície oclusal dos premolares e molares. Os valores de tensão no tecido ósseo foram obtidos através da tensão principal máxima, e a tensão no parafuso de fixação e no implante dentário foi obtida através dos critérios do mapa de von Mises. A simulação envolvendo a utilização da PEO reduziu as tensões nos parafusos de fixação, implantes dentários e osso cortical independentemente do material simulado (PMMA, EVA ou PEEK). A simulação com o uso da PEO resultou na redução das tensões nos parafusos de fixação, implante e tecido ósseo cortical, independentemente do material utilizado. A espessura da placa também se mostrou um fator relevante na diminuição de tensões nas estruturas analisadas. A PEO rígida de 3 mm de espessura e apresentou melhor benefício biomecânico. O uso da PEO foi eficaz na redução da tensão no parafuso de fixação, implantes dentários e osso cortical ao redor dos implantes, sendo que os materiais mais rígidos, como PEEK e PMMA, de 3 mm, apresentaram melhor comportamento biomecânico quando comparados ao EVA.

Palavras-chave: análise de elementos finitos; placas oclusais; próteses e implantes.

ABSTRACT

COSTA, L. A. **Biomechanical effects of different materials and their thicknesses for occlusal device on implant-supported single prostheses in overload simulation**: a 3D finite element analysis. 2025. Tese (Doutorado) – Faculdade de Odontologia, Universidade Estadual Paulista (UNESP), Araçatuba, 2025.

The aim of this study was to evaluate the effect of different materials used in the fabrication of occlusal devices and the different thicknesses of these materials in the stress distribution on screw-retained implant-supported single prostheses. 3D finite element analysis was used to evaluate occlusal overloads on the fixation screw, dental implant and cortical bone tissue around the implants corresponding to the posterior portion of the right maxilla, in the region of the first premolar, second premolar and first molar teeth. Ten models were simulated using specific 3D design programs to represent three single external hexagon implants (Ø 4.0 x 7.0 mm) with a screw-retained single metal-ceramic prosthesis. The occlusal device (OD) was simulated with three different materials: polymethylmethacrylate (PMMA), ethylene-vinyl acetate (EVA), and polyetheretherketone (PEEK), with thicknesses of 1 mm, 2 mm, and 3 mm. Furthermore, overload was applied to one model without OD. Finally, all geometries were exported for discretization in finite element software. In this same software, a static parafunctional load of 800 N was simulated on the ten models, in the axial direction, at 11 points on the occlusal surface of the premolars and molars. Stress values in the bone tissue were obtained through maximum principal stress, and the stress in the fixation screw and dental implant was obtained through the von Mises map criteria. The simulation involving the use of the OD reduced stresses on the fixation screws, dental implants, and cortical bone regardless the simulated material (PMMA, EVA, or PEEK). The simulation using an OD reduced the stresses in the fixation screws, implant, and cortical bone tissue, regardless of the material used. Plate thickness also proved to be a relevant factor in reducing stresses in the analyzed structures. A 3-mm thick, rigid OD provided the best biomechanical benefit. The OD was effective in reducing tension on the fixation screw, dental implants and cortical bone around the implants, with the more rigid simulated materials, such as

PEEK and PMMA with 3 mm thick, demonstrating better biomechanical behavior when compared to EVA.

Keywords: finite element analysis; occlusal splints; prostheses and implants.

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LISTA DE ABREVIATURAS E SIGLAS

CAD/CAM	Computer-Aided Design / Computer-Aided Manufacturing
EH	External hexagon
EVA	Ethylene-vinyl acetate
FEA	Finite element analysis
MPa	MegaPascal
N	Newton
OD	Occlusal device
PEEK	Polyetheretherketone
PMMA	Polymethylmethacrylate
%	Percent sign
Ø	Diameter

SUMÁRIO

1 INTRODUCTION

The use of dental implants has become an effective treatment for partial and total edentulous patients,[1] and the success rates in implantology is largely attributed to the osseointegration process.[2,3] However, biological and mechanical complications may impair the longevity of rehabilitations and may lead to the fracture or even loss of the crowns or dental implant and its associated components.[1-6] According to the literature, mechanical complications are more common than biological complications in implant-supported restorations.[4]

Implant characteristics such as length and diameter associated with its positioning in the dental arches may influence its success since mechanical failures are more likely to occur in implants with shorter lengths and smaller diameters compared to those with larger dimensions.[7] Moreover, there is a higher risk of failure in implants positioned in the region of maxillary premolars and molars which has been reported as an area of lower bone density and mechanical overloads.[6,8-11]

Bruxism is related to dental implant failure. This is a disorder characterized by involuntary teeth grinding and clenching during wakefulness and sleep.[12,13] The results found in recent systematic reviews showed that bruxism seems to be the most important risk factor that influences the late implant survival rate.[14,15] The occlusal overload caused by bruxism may lead to screw loosing, implant fracture and restorative crown failure (as chipping of the aesthetic material), fixture fracture, as well as promote peri-implant bone resorption.[16-18] A dental treatment for bruxism consists of an occlusal device (OD) to improve biomechanics as it absorbs the load generated by the parafunctional activity on the prosthesis, implant, and bone.[19] For patients with bruxism who require or are undergoing rehabilitation with implant-supported prosthetic crowns the inclusion of an OD in the treatment planning may promote long-term success rates.[20,21]

A wide range of designs and materials are used for the fabrication of OD,[22] such as polymethylmethacrylate (PMMA), ethylene-vinyl acetate (EVA), and polyetheretherketone (PEEK).[11] With the advancement of the digital technology of computer-aided design and manufacturing (CAD/CAM) new high-performance and technological materials have been studied end emerged for CAD/CAM system in order to develop new OD compositions.[23] PMMA, EVA and PEEK are also CAD/CAM materials recommended for CAD/CAM fabricated OD. These materials have different wear behavior and surface roughness pattern.[23] The results of an in vitro study evaluating the surface roughness of these materials demonstrated that an OD made from PEEK exhibited the lowest occlusal wear and lower volume loss after chewing simulation, followed by PMMA and EVA. EVA exhibited the highest occlusal wear.[23,24] However, the ideal OD thickness of each material to optimize the stress distribution and load absorption has not yet established.

The 3D finite element analysis (FEA) may be used to improve understanding and to demonstrate the biomechanical behavior of OD in simulations of implant-supported crowns in functional or overloads during clenching situations.[20] A previous study using FEA showed that in clenching and parafunctional loading models with OD relieved the unfavorable biomechanical behavior by a significant reduction of stress that was shared with the abutment screw and cortical bone tissue, particularly for single crowns.[25]

Understanding the biomechanical effect of the OD on implant-supported prostheses is important for the knowledge of the loads pattern distribution and for establishing biomechanically more favorable rehabilitation protocols, given that dental implants have been used in the clinical routine and that a part of the population may have developed or are likely to develop parafunctional habits such as bruxism.[26,27] Therefore, investigating the effect of the materials and their thickness for OD in bruxism patients may help determine whether it is a necessary intraoral appliance and which ones could offer better tension distribution after rehabilitation with implant-supported prostheses.

6 CONCLUSION

The use of OD was effective in reducing tension on the fixation screw, dental implants and cortical bone around the implants in 3D FEA simulation, with the more rigid materials, such as PEEK and PMMA, presenting better biomechanical behavior in simulated 3 mm thicknesses when compared with the simulation without OD.

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